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MODEL FORECASTS AND WORLD OBSERVATIONS OF THE OZONE LAYER (1960-1980)

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16. Abstract

A discussion of the theoretical and actual measurements of the decrease in global ozone is presented, with comparison and critique of reports published by NASA and the NAS.

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MODEL FORECASTS AND WORLD OBSERVATIONS OF THE OZONE LAYER (1960-1980)

The models currently forecast that a decrease of about 2% in the global ozone will have taken place before 1978 (NAS report, Nov. 79, p. 176; NASA report Dec. 79, p. 342) from the single cause of the chlorofluoromethanes F_{11} and F_{12}. /1*

But to be precise, we should add the effect of the anthropogenic compounds which have developed in parallel with the the chlorofluoromethanes (methylchloroform, chlorethylenes, etc.).

At the level of the stratosphere, this supply of supplementary chlorine represents about 50% of the CFC chlorine (NAS report, Nov. 79, p. 158; NASA report, Dec. 79, p. 87 (cf. appendix I); Penkett, Fabian, Schmidt, Nature, 1980).

If the theory is exact, we should thus observe a decrease in the total ozone on the order of 3%.

Examination of the theoretical distribution of this reduction as a function of altitude shows that the effect on the ozone layer between 32 and 45 km is 2 to 3 times greater than that predicted for the total ozone.

A reduction of 6 to 9% is therefore expected at this altitude.

Such forecasts can no longer be neglected, and we can hope to demonstrate this, despite the large natural variability of the ozone layer.

*Numbers in the margin indicate pagination in the foreign text.

A rigorous study of this possibility is essential, which in the final analysis will constitute the best verification of the theory on which the models operate.

Despite the affirmations of two recent reports published in the USA in [illegible date], it does not appear that such a study has actually been made.

1. Measurement of Total Ozone (Table 1) /2

The length of the period of past observations, as well as the enormous effort of control and sampling at the stations, and also the large number of stations, distributed throughout the world, make the Dobson network preferable for such a study. The satellite measurments which have been made up to now constitute a second global monitoring which in the recent past has given quite satisfactory agreement.

The NAS and NASA reports of 1979, moreover, stress this clearly, but in order to criticize immediately the corresponding results and to refute the possible detection of a trend of less than 5% for 10 years (NAS, p. 16; NASA, p. [number illegible]).

For its part, the U.K. DOE report of Nov. 1979 (p. 76) stresses that a trend of 2% is certainly detectible.

Point by point examination of the reservations expressed by the NAS and NASA reports is perplexing:

First, a general remark is absolutely necessary: although they agree on a threshold of near detectability, the two U.S. studies advance justifications and error components that are very different.

This disagreement is surprising, when we know that the NASA report was well known to the NAS committee before the month of August, and that no explanation is given for the differences.

In the case of the NAS report, the treatment of systematic errors

of possible [drift?] or bias in a manner identical to that of random noise errors is, however, difficult to accept.

Appendix 2 summarizes the observations which the differing reports have inspired on this subject. Here, we will limit ourselves to the points which seem to us most important:

A) Random Error

The different studies undertaken, notably by Parzen, Pagano and Watson within the framework of the CMA studies led to admitting random uncertainties (2 σ) on the order of 0.9% for six years and 0.8% for twelve years.

The conclusion of the study undertaken by the last of these authors for NAS and NASA resulted in retaining an error (2 σ) on the order of 0.8% (NASA report, 1979, p. 322), or about half that allowed by NAS.

B) Error in the Trend

Four causes of uncertainty have been advanced by the two reports, but with different values and types of errors:

- coefficients from the equipment or measurement; /3
- coefficients due to the localization of stations;
- long-term natural variations in O_3;
- various actions on the ozone by other anthropogenic emissions.

a) The causes of the coefficients linked to the measurement itself are estimated to correspond to a residual standard deviation for the average of 9 stations on the order of 0.8% by NASA. The greater contribution to this error is admitted to come from the effect of local tropospheric pollution (aerosol, O_3, etc.; p. 322 of the report), without which the mean instrument standard deviation would be only 0.37%.

Among the causes of tropospheric pollution, the effects of aerosols can be neglected (< 0.25% according to Shah, 1976). Only a possible increase in the tropospheric ozone could mask the effect of reduction by the CFC. This value seems hardly to be able to surpass 1%, according to NASA itself. Finally, these different effects can be felt only very weakly in the Southern hemisphere where anthropogenic pollution by unstable species is very weak.

Contrary to the indications of the NAS, the parasitic trend linked to a calibration coefficient is seriously reduced when we consider the mean number for all the stations, as the NASA report shows (p. 323).

b) The imperfect localization of the Dobson stations is considered by NASA susceptible of bringing about a decisive trend (1.5%). In fact, the study done by Miller (1979), to which the report refers, shows that for the period before 1978, this trend was negative and led to an apparent reduction in the ozone layer.

The past effect of the CFC can thus not be masked.

c) The unexplained long-term natural variations in the O_3 remain, along with the other possible anthropogenic effects on the stratospheric O_3, the only causes of a parasitic trend for the future.

It should be noted that no important anthropogenic effect can be seen for the past, apart from that of CH_3CCl_3 and other chlorine components which must be taken into account with the CFC.

d) The effect of emission of CO_2, CO, and H_2 linked to the use of fossil fuels thus can have only a relatively long-term important effect.

Among the natural variations, the probability of a relatively high [trend?], at the level of 5 to 6 years, becomes weak, when we consider the longer, 11-year durations of the solar cycle.

If, extraordinarily, it existed, it would correspond to a phenomenon with very great inertia which would not be rapidly reversed, thus leaving the time largely for ozone monitoring of [illegible] to the future, the possible usefulness of regulatory measures.

In conclusion, it thus seems that the data from the Dobson network for the period 1960/1978 should allow detecting an effect of the anthropogenic chlorine compounds as soon as they attain a level near 3% in the Northern hemisphere and much less in the Southern hemisphere. /4

C) Comparison with the Models

Graph 1 includes the latest preliminary data collected in the latest ODW (ozone data for the world) publications in 1979. It shows no negative trends in the total ozone in the Northern and Southern hemispheres.

This conclusion is in agreement with most of the recent publications ([illegible date] and 1979) which have studied the total O_3 trends according to the Dobson measurements (Miller, Angell/Korshover) or the ozone [illegible] measurments (Angell/Korshover).

We can thus conclude that the maximum reduction in ozone caused by all the emissions of anthropogenic chlorine compounds emitted since 1955 is clearly less than 1%. The conclusions of the theoretical models which forecast a reduction of 3% are thus clearly denied.

2. Measurement of Ozone in Upper Stratosphere (Table 2)

A certain number of the better Dobson network stations have undertaken more or less systematically for more than 15 years measurements of the vertical O_3 profile, by measuring the Umkehr effect.

Regular launching of balloon sondes equipped for measurement in situ of the O_3 have also allowed the preparation of profiles up to 32 km since 1968.

Finally, many satellites have been launched since 1967 with equipment that allows finding the same profiles. The data have not yet been published, but they should furnish very precise indications, in particular for the upper ozone layer, where their precision is the best.

In contrast to the NASA report, the NAS does not think it useful to study the data from these various measurements, although their importance has frequently been noted.

Appendix 3 details the remarks which can be made about the NASA report.

The conclusions of our study on the possibility of using the Umkehr data to acertain a possible trend in the upper O_3 layer are the following.

A) Random Error

For the 32-46 km layers, De Luisi (1979) gives a standard deviation on the order of 9% (taken from the NASA report) for one station and one isolated measurement.

For a total of 10 stations and 4 measurements per month on average, we must thus figure statistically on a standard deviation on the order of 1.4% as the monthly mean, and 0.85% for the seasonal mean.

Angell and Korshover (1979) note an experimental seasonal standard deviation of 1.5%, which is in good agreement with this forecast if we note that the latter includes variability in the O_3.

The 5% figure retained by the NASA report is thus quite exaggerated. If we consider the general development over a sufficient number of years (at least 10, for example), we can estimate the trend by averaging the measurements over periods on the order of 2 years. Basing our results on Angell's figures, we thus find a standard deviation on the order of 0.5%, and therefore a random error in the trend on the order of 1%.

B) Errors in the Trend

The following are the four major causes of error noted with regard to the total O_3:

a) The error linked to the measurement itself depends particularly on possible interference of stratospheric or tropospheric aerosols and on the possibility of calibration drift. Possible calibration drift is similar to that foreseeable in the case of total ozone; the number of stations is smaller, and it can be admitted that it could be slightly more important: 0.5%, for example (to allow 1%, as the NASA report indicates, seems excessive for 10 of the best Dobson stations. /6

The error linked to development of tropospheric aerosols would generally be weak, in the direction of a reduction in O_3.

That due to stratospheric volcanic errors is certainly important, but as De Luisi (1979) has shown, it is of very short duration (2 to 3 years). Thus it cannot influence the trend over a period on the order of 10 years.

b) The effects of a biased geographical distribution are considered very important by NASA. A figure of 5% is

proposed, but with no exact justification. If such a bias is conceivable, we do not see how such an error could contaminate a prolonged trend over 10 years, when we consider that the stations in the temperate zone of the Northern hemisphere cover all the latitudes from 20 to 55°, and three zones of longitude centered approximately at 5, 75 and 135° East.

c) The natural effects that can influence the ozone content are essentially a possible trend in temperature and/ or a continued variation in solar flux.

The variation in temperature of the upper stratosphere is thought to bring about a risk of error on the order of 2%, according to NASA. Like solar flux, this seems not very probable, if we consider periods of observation at least equivalent to the solar cycle.

C) Comparison with the Models

The examination of the different reasons for errors shows that we should be able to detect a variation in the upper O_3 layer on the order of 2%, if the examination period is long enough to eliminate parasitic trends linked to the solar cycle and geographical sampling errors linked to temperature distribution in the upper stratosphere.

The use of satellite data now being gathered should soon add essential information to the subject.

In any case, Graph 2 clearly shows that no reduction in the upper ozone layer has been verified even if the models forecast a reduction on the order of 6 to 9%. In spite of the variations observed, on the scale of periods of several years, on the order of 8 to 10% in relation to the causes of errors noted by NASA, we can formally conclude that there is disagreement between the observations and the theory of the models in the period 1960-1978.

3. Conclusion

Both the measurements of total O_3 and those of the upper stratospheric layer contradict the theoretical forecasts of the models when one examines the past 15 years.

This coincidence of conclusions is even more convincing inasmuch as the causes of errors capable of influencing these two types of measurements are for the most part of different types.

TABLE 1. SUMMARY OF EVALUATIONS OF ERROR

	NAS	NASA	[a]CHIFFRES PROPOSÉS POUR LA PERIODE 1960/
:UR ALEATOIRE [b]	σ = 0,75 %	σ = 0,6 %	σ = 0,4 %
·T SUR LA MESURE [c]	σ = 1,6 %	σ = 0,8 %	ERREUR[g] MAXIMUM DE L'C DE : 0,5 % → HEMISPHERE[h] 1,5 % → HEMISPHERE[i]
·T LIE A L'ECHANTIL-NAGE GEOGRAPHIQUE [d]	σ = 0,5 %	σ = 1,5 %	? ERREUR[j] $\leq$ 0
IATIONS NATURELLES & IROPOGENIQUES DE O_3 [e]	σ # 3,5 %	σ = 2,2 %	ERREUR[k] POSSIBLE EXPLI DE L'ORDRE DE 0,4 %
AL	σ # 4 % SOIT ERREUR[f] = 2σ = 8 %	σ = 2,8 % SOIT ERREUR[f] = 2 σ = 5,6 %	[l] σ = 0,4 % + ERREUR DE DRIFT DE 0,9 % DANS[m] L'HÉMISF 1,9 % DANS[n] L'HÉMISF

Key to Table 1 on following page.

Key to Table 1.

a. figures proposed for the period 1960-1979
b. random error
c. measurement drift
d. drift connected with geographical sampling
e. natural and anthropogenic variations in O_3
f. or error
g. maximum error on the order of:
h. Northern hemisphere
i. Southern hemisphere
j. error
k. possible explainable error on the order of 0.4%
l. drift error of:
m. in the Southern hemisphere
n. in the Northern hemisphere

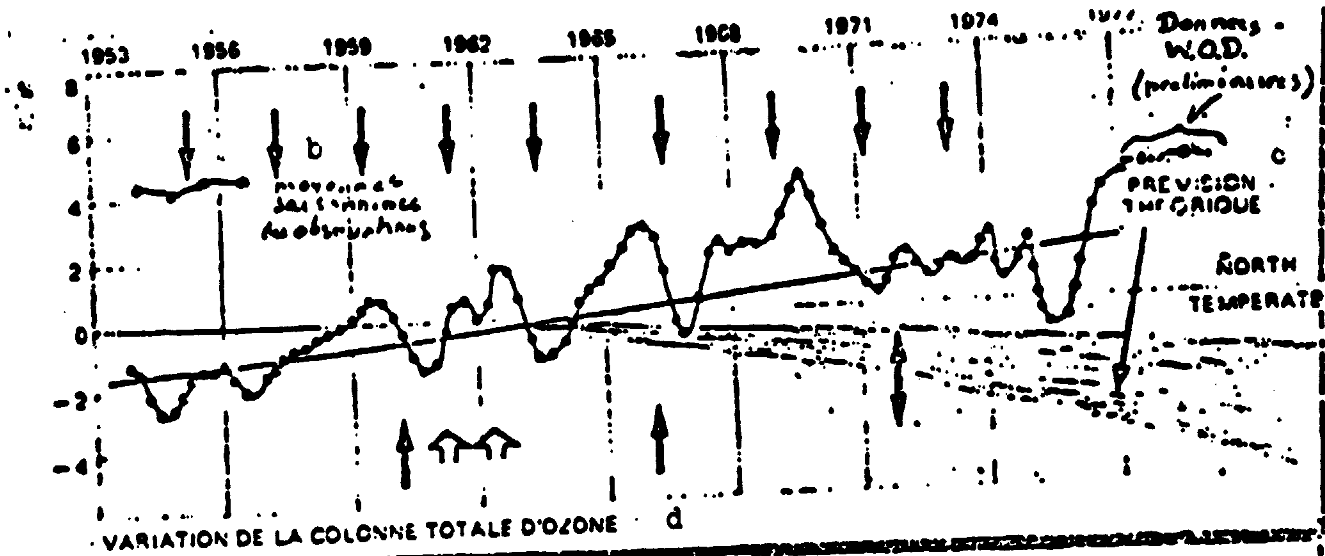
TABLE 2. SUMMARY OF EVALUATIONS OF ERROR

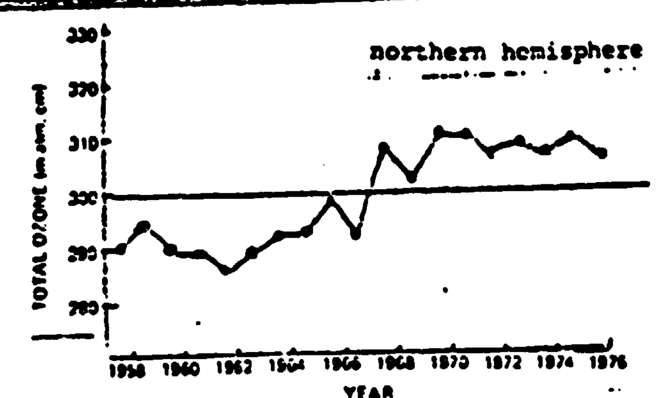
	NASA	[a] CHIFFRES PROPOSÉS POUR LA PERIODE 1960/197
ERREUR ALEATOIRE [b]	$\sigma = 5\,\%$	[g] $\sigma = 0{,}4\,\%$ SUR LA MOYENNE ANNUELLE
DRIFT SUR LA MESURE [c]	$\sigma \neq 2{,}3\,\%$	ERREUR $\leqslant 0\,\%$
DRIFT LIE A L'ECHANTILLONNAGE GEOGRAPHIQUE [d]	$\sigma = 5\,\%$	[h] ERREUR NEGLIGABLE POUR 15 ANS
VARIATIONS NATURELLES & ANTHROPOGENIQUES DE O_3 [e]	$\sigma \geqslant 2{,}5\,\%$	[i] ERREUR DE 1 À 2 % EXPLICABLE
TOTAL	[f] $\sigma = 7{,}8\,\%$ SOIT ERREUR = 2σ = 15,6 %	[j] $\sigma = 0{,}4\,\%$ SUR LA MOYENNE ANNUELLE + DRIFT PARASITE EVENTUE DE 1 À 2 % EXPLICABLE

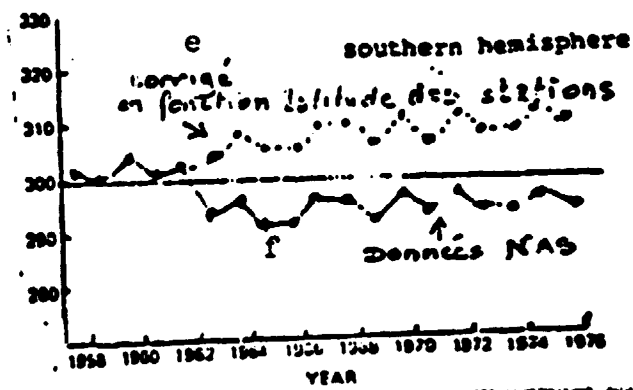
[Key to table on following page.]

Key to Table 2.

a. figures proposed for the period 1960-0979
b. random error
c. measurement drift
d. drift connected with geographical sampling
e. natural and anthropogenic variations in O_3
f. or error
g. for mean annual error
h. error negligible for 15 years
i. explainable error of 1 to 2%
j. for annual mean + possible parasitic drift of 1 to 2% explainable







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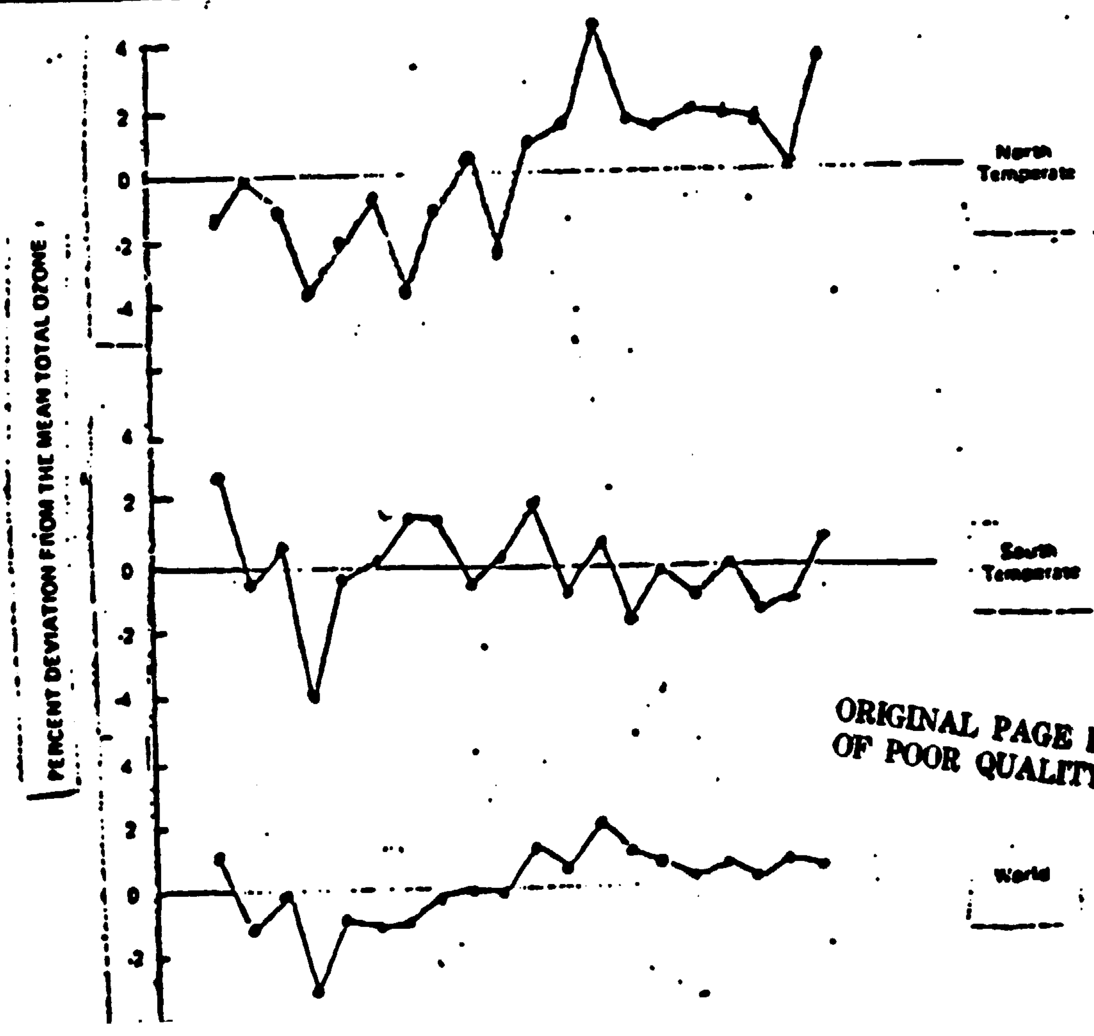

NAS

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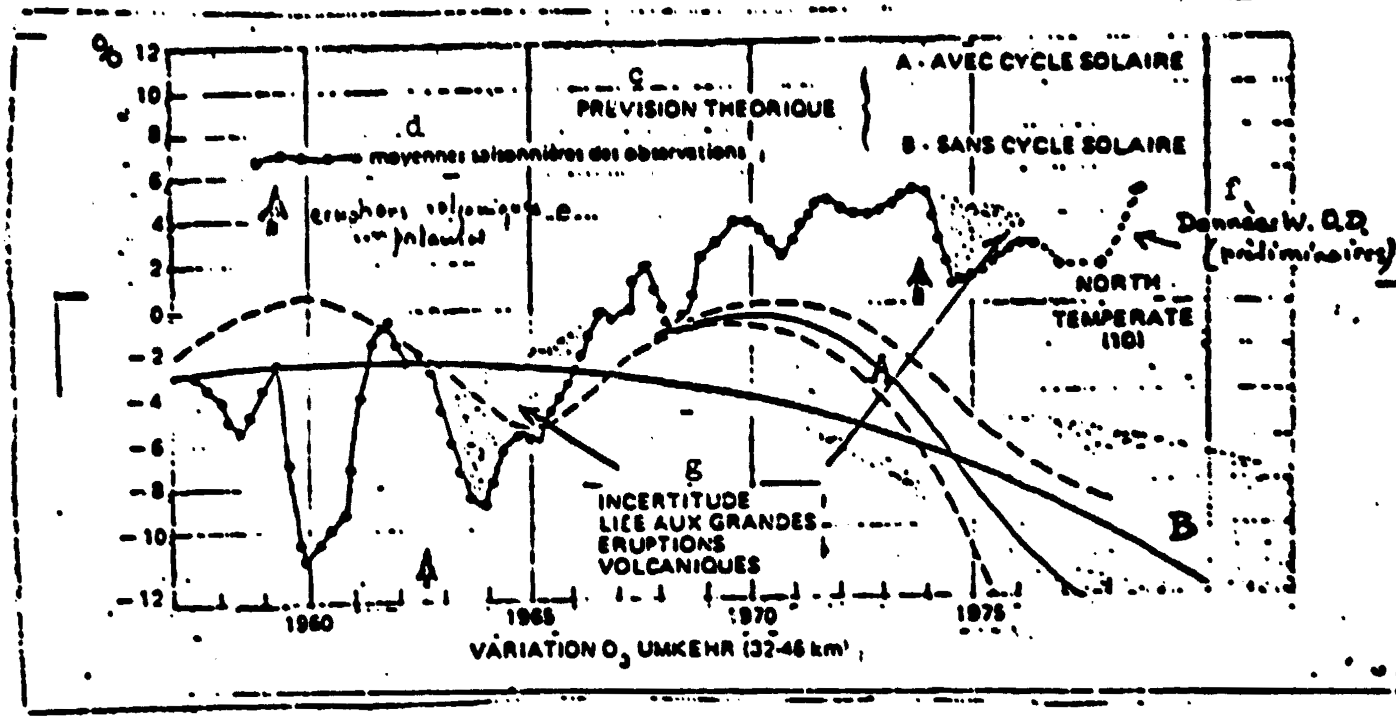
[Keys on following page.]

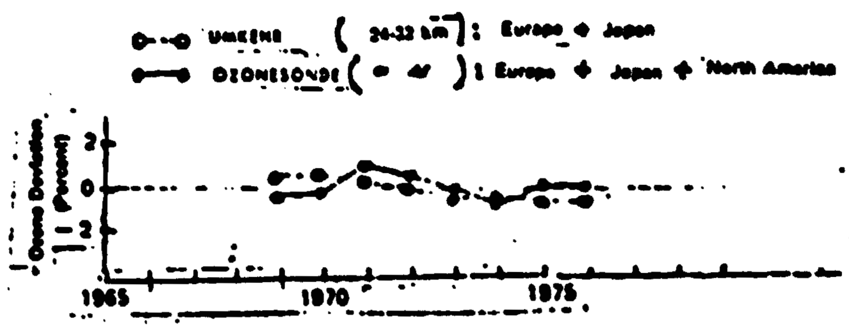
Key:

a. WOD data (preliminary)
b. seasonal mean of observations
c. theoretical forecast
d. variation in total ozone column
e. corrected as a function of altitude of the stations
f. NAS data



h
D'APRES J. K. ANGELL AND J. KORSHOVER (1978)

ET W.O.D.C.



i
D'APRES J. K. ANGELL AND J. KORSHOVER (1979)

[Keys on following page.]

Key

a. with solar cycle
b. without colar cycle
c. theoretical forecast
d. seasonal means of observations
e. important volcanic eruptions
f. WOD data (preliminary)
g. uncertainty linked to large volcanic eruptions
h. from J.K. Angell and J. Korshover (1978) and W.O.D.C.
i. from J. K. Angell and J. Korshover (1979)

Appendix 1

Contribution to the Stratospheric Cl /12

	NAS 1979	Penkett/Fabian Schmidt (Nature) 3.1.1980	NASA (1979)
CFC 11 & 12	34 %	30,8 %	29 %
CCl_4	20 %	19,3 %	23,5 %
CH_3CCl_3............................	12 %	23 %	13,6 %
Autres composés anthropogéniques[a] .	9 %		?

Key

a. Other anthropogenic compounds

The curve of development of global production of CH_3CCl_3 and other anthropogenic compounds (except CCl_4) is practically parallel to that of the CFC 11 and 12.

Appendix 2

[first page missing]

...individual and n the number of independent stations. σ can be estimated with enough precision from measurements made during a reference period with all the stations considered /13

$$\sigma \neq s = \sqrt{\frac{\Sigma (x_i - x_m)^2}{n - 1}}$$

x_i is the individual measurements and x_m the mean measurement.

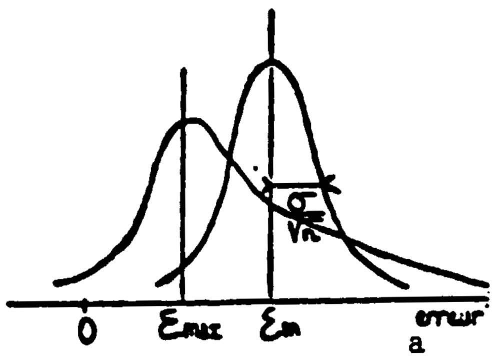
The distribution of errors is Gaussian and it is known that the error for the mean at 95% confidence is less than $2\frac{\sigma}{\sqrt{n}}$.

This treatment is exactly that used by NAS and NASA for evaluating mean noise, but it should be noted that the reference time interval was not detailed, which brings about a serious confusion in the discussion of error values.

2) Errors Connected to the Possibility of a Local Trend Specific to Each Station

This is, for example, the case of calibration drift, local tropospheric pollution (O_3, aerosols, various pollutants), etc.

The measurement drift at each point from the beginning of the long period of observation of the trend will correspond to an ε value for each of these causes and for each station considered independently. If the number of stations is very large, the total of the ε values will not necessarily be distributed according to a Gauss curve. In particular, in the case of drift due to local pollution, there is a risk that it will approach much closer to a log normal distribution, that is a Poisson distribution. The mean εm of the measurement will thus be distributed according to a Gaussian law, but centered on a value different from that most frequently observed at the end of a reference period (cf. figure) which is long enough to be representative of the period of study of the O_3 trend.



Key: a. error

On the global level, each case of drift is expressed by a mean drift εm to which is added a standard deviation error $\sigma/\sqrt{n}$. The values of εm and of this standard deviation will be difficult to estimate because they should be determined taking into account observations separated by a

period close to that in which we wish to determine the O_3 trend.

It is not clear in the NAS and NASA reports if the standard deviations in question correspond well to that defined above

$$\sigma \neq s = \sqrt{\frac{\Sigma(x_i - \Sigma_n)^2}{n}}$$ /14

and the presence of a non-random εm component seems not to be taken into account. This is added as an algebraic value and not in the form of its square, like the standard deviations.

3) Effects of Drift on the Global Level

In principle, this is the case of effects on the stratosphere or coming from space.

For example: mean drift in O_3 linked to anthropogenic stratosphereic effect; long-term natural variations in mean stratospheric O_3; various long-term stratospheric pollutions; variation in solar flux; change in characteristics of the mesosphere and ionosphere, etc.

The parasitic drifts cannot be treated as random errors. They are manifested at each station by a fixed, long-term trend, masked by the variability (errors of type 1) and possible individual trends (errors of type 2).

Any calculation of standard deviation can only show errors already taken into account, and in no way the errors foreseen here.

A practical consequence is that we can never add these errors by their squares like random errors. Either they exist and are added algebraically, or they do not exist.

Nevertheless, it seems that the NAS and NASA reports treat these errors with their standard deviations!

4) Errors Due to Geographically Biased Sampling

Such errors cannot exist unless we admit that there exist globally wide zones with specific characteristics that are relatively stable on the scale of several years and that drift or develop slowly over more than 10 years.

Statistically this is shown by a slippage of the mean obtained with the observation network in relation to the global mean. This slippage is brought about without changing the other causes of error if the possibility of interaction between second-order errors is neglected.

This slippage can in no way be treated like a random error with standard deviation, contrary to what NAS and NASA seem to have done.

2. Estimation of Causes of Errors /15

	NAS	NASA
Random Errors (Residual noise on the mean measurments)	$\sigma = 0.75\%$ Mean between the estimates made by Hill and those made by Watson for 9 stations and monitoring periods of between 6 and 15 years.	$\sigma = 0.6\%$ Mean between the evaluation made by Hill and Watson for 9 stations and a period on the order of 10 years.

Observations

It is actually probable (cf. report of U.K. Department of Environment, p. [illegible]) that the noise can scarcely be improved by increasing the number of stations to more than a dozen.

It is more valuable to retain the σ value calculated by Watson on the basis of the more complete studies of Parzen Pagano

$$\sigma = 0.4\% \text{ for one decade}$$

		NAS		NASA		
a Erreurs de Mesure	b Dérive de la cte solaire	possible	i Évaluation subjective (moyenne entre 0,5 et 1 % ?) σ_m = 0,75 %	j erreur de ± 0,3 % d'où σ = 0,2 pour l'ensemble des stations et 10 ans d'observation	σ 1 station = 2,3 %	σ_m 9 stations = 0,8 %
	c Dérive de la t° stratosph.	possible		k erreur de ± 0,5 % d'où σ = 0,3 pour 1 station et 10 ans d'observation		
	d Dérive d'étalonnage	f risque de dérive car pas de régularité périodique des étalonnages ?		l erreur de ± 1 % d'où σ = 0,9 pour 1 station et 10 ans d'observation		
	e Dérive du fait de "Haze and aérosols" et pollution troposphérique	g turbidité du ciel erreur possible de 0,2 à 0,5 % pour 10 à 20 ans (pas de justification donnée) h Aérosols volcaniques et non volcaniques ? erreur possible de 0,3 à 0,5 % pour 10 à 20 ans (pas de justification donnée)	σ_m = 0,75 %	m changement des aérosols sur 10 ans et 1 station erreur de ± 1 % n changement O_3 troposph. sur 10 ans et 1 station erreur de ± 1 % o changement autres polluants (SO_2,...) sur 10 ans et 1 station erreur de ± 2 % p changement de la couverture nuageuse sur 10 ans et 1 station erreur de ± 1 %		

Key: a. Measurement errors
b. Drift of solar cte [expansion unknown]
c. Drift of stratospheric t° [expansion unknown]
d. Calibration drift
e. Drift due to haze and aerosols and tropospheric pollution
f. risk of drift due to lack of periodic regularity of calibration ?
g. turbidity of sky: possible error of 0.2 to 0.5% for 10 to 20 years (no justification given)
h. Volcanic and nonvolcanic aerosols? Possible error of 0.3 to 0.5% for 10 to 20 years (no justification given)
i. Subjective evaluation (mean between 0.5 and 1%?)
j. error of ± 0.3% when σ = 0.2 for all stations and 10 years of observation
k. error of ± 0.5% when σ = 0.3 for all stations and 10 years of observation
l. error of ± 1% when σ = 0.9 for all stations and 10 years of observation

Key continued on following page

Key to Table on page 19 continued

m. change in aerosols over 10 years and 1 station, error of ± 1%

n. change in tropospheric O_3 over 10 years and 1 station, error of ± 1%

o. change in other pollutants (SO_2...) over 10 years and 1 station, error of ± 2%

p. change in cloud cover over 10 years and 1 station, error of ± 1%

Observations

1. The effect of variations in the equipment constants seems clearly overestimated and is not justified in the NAS report. NASA's evaluations seem to be more thorough. However, the evaluation remains subjective and since at this stage some confusion exists between random error and mean drift at the global level, it hardly seems possible to guarantee the validity of the figures proposed. Among other things, it seems difficult to allow that for calibration error the number of independent [stations ?] could be limited to 9. Under these conditions, the σ for the corresponding mean is practically negligible and is not equal to $0.9/3 = 0.3$. In addition, as NASA admits, in this case no possibility of non-random drift is granted (ϵ from Par. 1).

	NAS	NASA
representativeness of localization of stations	possibility of effect on the trend corresponding to $\sigma = 0.5\%$ (evaluation not justified in the text)	$\sigma = 1.5\%$ extrapolated from the study published by Miller in 1979 for the zone 50° N and the period 1965-76 (error due to absence of polar stations is negligible, $\sigma = 0.3$)

Observations

Miller's study concludes with a maximum deviation between the ends of the period forecasted to be on the order of ± 2% (or 2 times weaker

than that cited by NASA). In fact, the curve given by this author shows instead a deviation of ± 1, if the punctuation marks are excluded. Moreover, this deviation runs in the direction of a decrease in the trend. In no case, therefore, at least for the Northern hemisphere where the study was done, can the reduction of O_3 by the CFC be masked, but, on the contrary, it is reinforced.

error for the trend ≤ 0

	NAS	NASA
a variations naturelles à long terme de O_3	c σ = 3,1 % évaluation déduite de l'observation d'une augmentation de l'O_3 moyen dans l'hémisphère Nord de 6 % entre 1962 et 1973 la NAS n'ose cependant pas l'introduire formellement dans son calcul d'erreur de trend !	σ = 2 % f On calcule d'après les variations des données géophysiques et météorologiques passées un trend natural de O_3 possible de 1 à 3 % sur 10 ans on note cependant que la période du cycle solaire est prépondérante dans les variations observées.
b effets anthropogéniques parasites sur O_3	d CO_2 ⟶ 2 % dans 100 ans CO, H_2 ⟶ 5 % dans 100 ans e soit environ 0,2 % et 0,5 % pour 10 ans	σ = 1 % g sont inclus dans ces effets CO_2 - N_2O - CH_3CCl_3 - CO - H_2O ...

/18

Key:

a. long-term natural variations in O_3
b. parasitic and anthropogenic effect on O_3
c. evaluation deduced from observation of an increase in mean O_3 in the Northern hemisphere of 6% between 1962 and 1973. The NAS does not venture to introduce this formally in its calculation of error in the trend!
d. in 100 years
e. or about 0.2% and 0.5% for 10 years
f. This is calculated according to variations in geophysical and meteorological data from the past a natural trend in the possible O_3 of 1 to 3% over 10 years. It is noted, however, that the period of the solar cycle is heavily weighted in the variations observed.
g. are included in these effects

Observations

1. The effect of anthropogenic chlorine compounds such as CH_3CCl_3 should be treated with the CFC. It makes clearer the lack of verification of the series and should not be attenuated as intended by the text of the NASA report.

2. The effect of agricultural N_2O is appreciable only in the case of a considerable increase in the stratospheric Clx. Moreover, it could be a kind of "antidote." In any case, it has played a minor role in the past period.

3. The effect of CO_2, CO and H_2 from combustion gases will begin to be appreciable only in the future, because it is not linear as a function of time. The study of J. Logan (1978) shows that, in fact, the effect up to 1978 should not surpass 0.1 to 0.28% for CO and H_2, and 0.15% for CO_2.

4. The long-term variations in O_3 are probably weak when the observation of the trend is followed over a period much longer than half a solar period.

possible explainable error
on the order of 0.4% maximum

Appendix 3. Ozone in High Stratospheric Layers /19

1. General Remarks

Cf. Appendix 2; the same considerations remain valid for this ozone layer.

2. Estimate of Causes of Errors

	NASA
a Erreur aléatoire de mesure (bruit) d-	b pour 1 station σ = 7 % à c 30 km σ = 9 % à 40 km e d'où c σ = 5 % à 40 km f (5 stations indépendantes) basé sur les travaux de De Luisi en admettant une erreur de 5 % sur la mesure optique

Key:
a. Random measurement (noise) error
b. for 1 station
c. at
d. based on the works of De Luisi, admitting an error of 5% for optical measurement
e. when
f. 5 independent stations

Observations

A measurement error on the order of 1.5 to 2% seems more reasonable on the basis of the statistical study of this error carried out on 8 Dobson devices in 1974 by Belsk (Walshaw, La météorologie VI/12, March 1978), with a σ of 7% at 40 km and 4% at 30 km. According to De Luisi (1 measurement), for the mean figure for 1 year, one should not use 5 independent measurements, but at least 200 for the Northern temperate zone (10 stations, 4 measurements per month). A low statistical error thus results.

$$\boxed{\sigma \simeq 0{,}4\ \%}$$

		NASA
Drift du à la mesure a	Dérive d'étalonnage b	f liée à l'étalonnage du réseau Dobson $\longrightarrow$ 1 % pour 10 ans g
	Dérive de la t° stratosph. c	h comparable au cas de O_3 total $\longrightarrow \pm 0,5$ %
	chg^t du flux solaire d	i néant
	Haze et Aérosols e	$\sigma = \pm 2$ % j moyenne de la fourchette 0 à 4 % donnée sans justification k l'effet des aérosols troposphériques apparaît relativement négligeable (à concentration égale 10 fois moins d'effet)

Key: a. Drift due to measurement
b. Calibration drift
c. Stratospheric t° [expansion unknown] drift
d. Change in solar flux
e. Haze and aerosols
f. linked to calibration of Dobson network
g. 1% for 10 years
h. comparable to the case of total O_3
i. nothing
j. mean of the fork 0 to 4% given without justification
k. the effect of tropospheric aerosols appears relatively negligible (at equal concentration, 10 times less effect)

Observations

Calibration: a cause of drift equivalent to that admitted for total O_3 should be retained; 0.3% for 9 independent stations (approximately the case here for the temperate Northern hemisphere).

Aerosols: the error is negative, since it intervenes in increasing the light flux by diffusion. Also, the duration of the effect of volcanic aerosols is weak over the period of observation of the trend.

error for the trend < 0

	NASA
a Erreur liée à l'échantillonnage géographique	b $\sigma = 5$ % par le biais d'une répartition de la température stratosphérique éventuellement non homogène Pas de justification précise Effet de l'absence de stations polaires faibles $\sigma = 0{,}5$ %

Key: a. Error linked to geographic sampling
b. for the bias of a stratospheric temperature distribution that may be non-homogeneous. No exact justification. Effect of absence of polar stations is weak.

Observations

We lack long-term stratospheric data for temperature, but there are some series that are long enough (since 1960). The trend has never been observed for longer than half the 11-year solar period.

One can thus allow a negligible error detected in the trend over a 15-year period.

	NASA
a VARIATIONS PROLONGEES NATURELLES DE L'O_3	c CHANGEMENT POSSIBLE DU SPECTRE SOLAIRE $\rightarrow \sigma = 1$ % (AUCUNE JUSTIFICATION) d CHANGEMENT DE TEMPERATURE $\rightarrow \sigma = 2$ % (REDACTION NASA PEU CLAIRE LAISSANT CROIRE A UNE CONFUSION AVEC L'EFFET SUR LA MESURE)
b VARIATIONS PROLONGEES DE L'O_3 ANTHROPOGENIQUES	e LES EFFETS DUS À CO_2 SONT PLUS GRANDS QUE DANS LE CAS DE L'O_3 TOTAL

Key: a. prolonged natural variations in O_3
b. prolonged anthropogenic variations in O_3
c. possible change in solar spectrum (no justificiation)

Key to this table continued on following page

Key to Table on page 25

d. temperature change (NASA publication less clear, letting one believe in confusion with the effect on the measurement)
e. effects due to CO_2 are greater than in the case of total O_3

Observations

1. The natural variations outside the period of the solar cycle cannot be excluded, but if they exist, they are small and have great inertia. No reversing of the trend, if one existed anyway, should be seriously feared. The CFC effect should be examined in this context, and from this fact, these possible phenomena bring about no supplementary risk.

2. The past effect of CO_2 on the high O_3 layer is perhaps not negligible; but it seems difficult to envisage an effect much greater than 1%, according to the study of Luther-Chang (J. of Geo. Research, Oct. 1977) for the past period.

Drift Errors for the Dobson Network /22

I. Effect of t^o Trend on Absorption Coefficient

According to Powell, 1971, ± 5% → ± 0.5% error on the O_3 content in the vicinity of the maximum atmospheric O_3.

According to the measurements of t^o from 1957 to 1976 (radiosonde and rocket probe) recounted by Angell and Korshover for 16-24 km, we note a variation on the order of 1^o over 20 years and 1.5^o over 10 years. A mean error thus results of -0.1% over 20 years and ± 0.15% over 10 years.

II. Calibration Drift

The error admitted by NASA in 1979 is on the order of ± 3% for 10% of the stations, and it is negligible for 90% of the stations. This leads to a standard deviation on the order of 0.9 for one station.

For all the stations of the network (about 50), the standard deviation is only 0.9/7 = 0.13.

NASA mistakenly has chosen a division by $\sqrt{9}$ (9 stations), and it is not justified to consider that the calibration errors are correlated beyond 9 stations.

III. Spectral Variation of the Sun

0.3% error cited by NASA in the case of solar cycles. For longer durations, this variation can be neglected.

IV. Change in Observation Conditions (Clouds)

NASA admits ± 1% for each station. As with the calibration, there is no reason to limit the number of stations to 9. The uniformity of distribution of the error at 1% gives a σ per station of 0.6 with $\sigma_{mean} = 0.6/7 = 0.09$.

V. Tropospheric Pollution Trend

Tropospheric O_3: Komhyr (1980) notes that the mean content of tropospheric O_3 in the region of Delft is on the order of 0.5% of the total O_3. It seems that this figure gives an upper limit to the possible mean error.

NO_2, SO_2: the same article of Komhyr leads one to allow an annual mean of 0.5% for some stations both for SO_2 and for NO_2. Allowing that 10% of the stations have this situation, and that the others show negligible pollution because of the nearness to the tropospheric base, we obtain $\sigma = 0.16$ for an isolated station or σ# 0.02% for the average of 50 stations [next line missing].

-Aerosol: Shah's article in 1976 indicates an error on the order of 0.5% is possible for one station. If we allow that all the stations are polluted and that they have all developed in terms of quantity and /23

type of aerosols, one finds a negligible error over the average of 50 stations = 0.5/7 = 0.07.

Global error is thus in the end practically limited to the error possibly introduced by the O_3. It should be noted that this error, on the order of 0.5%, does not exist in the Southern hemisphere, taking into account the tropospheric life spans of O_3 and the exchange times for the two hemispheres.

VI. Geographic Sampling

Miller's publication, to which NASA refers, shows that in the temperate zone of the Northern hemisphere, the maximum possible error for the past period was on the order of -1.5%. In fact, this error in this period does not risk masking a reduction in O_3, but, on the contrary, making one appear.

On the global level, taking into account the smaller variability in pressure zones in the other global zones, we can count on a maximum possibility of error in both directions in an undefined period on the order of 0.55% (accepting the factor chosen by NASA).

Umkehr Errors for O_3 /24

Statistical Errors

The σ given by Angell and Korshover are, respectively, on the order of 0.85 and 1.65 for the total Dobson O_3 and the 32-46 km Umkehr O_3.

On the basis of this report, we can allow a statistical error trend for the Umkehr layers about 2 times greater than for the Dobson O_3, corresponding to a σ # 2%. In fact, this should be weaker, if we take into account the weaker spatial and temporal variability at this altitude zone.

Instrument Errors

Stratospheric t° Drift

This variation has been on the order of 4 to 5°. On the basis of Powell's 1971 coefficient of error, we obtain an error on the order of ± 0.5%.

Aerosol

The volcanic aerosols only have a negligible effect after 3 years (cf. De Luisi). The total tropospheric and stratospheric aerosols can moreover only give decreases in the high Umkehr O_3 layer. It is scarcely probable that one could observe a positive drift which would presuppose a decrease in particulate pollution.

Calibration Errors

An error near that of Dobson, ±0.5%, should be observed.

Spatial Error (Geographic sampling)

This should be near that of the total O_3, since the smaller spatial variability at these altitudes compensates for the smaller number of stations.

Errors Due to Anthropogenic Effect

Primarily CO_2 should give a drift of about 1%.

DRIFT AND PARASITIC TREND

OBSERVATIONS 1960/1979

	[a] ERREUR INSTRUMENTALE (DERIVE ALEATOIRE)					[e] ECHANTILLONNAGE GÉOGRAPHIQUE	[f] CAUSES POSSIBLES D'AUGMENTATION ANTHROPOGÉNIQUE DE O_3 STRATOSPHÉRIQUE	[g] DÉRIVE MAX POSSIBL
	T° (COEF.ABS.)	[b] ETALONNAGE	[c] SPECTRE SOLAIRE	CHANG.T [d] CONDITION OBSERV.	POLLUTION TROPOS.			
OZONE TOTAL DOBSON	± 0.15 %	± 0.26 %	[h] NÉGLIGEABLE	± 0.2 %	[i] + 0.5 % O_3 (SURTOUT) DANS HÉM. NORD (NÉGLIGEABLE DANS HÉM. SUD)	[j] 0 À - 1.5 % DANS LA ZONE TEMPÉRÉE NORD [k] (± 0.55 % SUR LE GLOBE)	+ 0.4 % (CO_2 - CO - H_2)	+ 1.3 [l] (0.8 % HÉM. S
	± 0.36 %							
OZONE UMKEHR 35/45 KM	± 0.5 %	± 0.5 % MAXIMUM	[h] NÉGLIGEABLE		[m] NÉGLIGEABLE (OU NÉGATIVE)	[n] DE L'ORDRE DE CELLE DU DOBSON ± 0.5 %	[o] + 1 % (CO_2 ESSENTIELLEMENT)	+ 2

Key to Table on page 32-Drift and Parasitic Trend

a. instrument error (random drift)
b. calibration
c. solar spectrum
d. change in observation condition
e. geographic sampling
f. possible causes of anthropogenic increase in stratospheric O_3
g. maximum possible drift
h. negligible
i. (especially) in Northern hemisphere (negligible in Southern hemisphere)
j. in Northern temperate zone
k. global
l. Southern hemisphere
m. negligible (or negative)
n. on the order of that of Dobson
o. essentially

Key to Table following on page 34

Limitation in Possible Reduction of O_3 by World Monitoring (After 10 Years of Observation)

a. limits of observation error
b. random statistical error
c. possible coefficient or bias
d. possible total error = detection threshold for 10 years
e. risk of maximum reduction of mean total O_3 (detection threshold + overshoot)
f. (1% without representative geographic control)
g. (0 to 2% without geographic control)
h. (possibility of suppressing sampling error)

Key to Table following on page 35

Contradiction Between Theory and Trend, O_3, 1960-1979

a. limits of observation error
b. decrease
c. statistical
d. derivatives and possible parasitic trend
e. total possible error for trend
f. theoretically observable (model theoretical reduction = total error)
g. actually observed
h. on the order of
i. Northern hemisphere
j. Southern hemisphere

LIMITATION IN POSSIBLE REDUCTION OF O_3 BY WORLD MONITORING (AFTER 10 YEARS OF OBSERVATION

	[a]ERREURS LIMITES SUR OBSERVATIONS			"OVERSHOOT"	[e] RISQUE DE RÉDUCTION DE O_3 TOTAL MON (SEUIL DE DÉTECTION OVERS
	[b] ERREUR STATISTIQUE ALÉATOIRE	[c] DÉRIVÉ OU BIAIS POSSIBLE	ERREUR TOTALE [d] POSSIBLE = SEUIL DE DÉTECTION SUR 10 ANS		
OZONE TOTAL DOBSON	± 1 %	[f] 0,8 % (1 % SANS CONTRÔLE REPRÉSENTATIF GÉOGRAPH.)	- 0,2 A + 1,8 % [g] (0 A + 2 % SANS CONTRÔLE GÉOGRAPHIQUE)	0,6 %	2,4 % A 2,(
OZONE UMKEHR 35/45 KM	1,5 % A ± 2 %	1 % [h] (POSSIBILITÉ DE SUPPRIMER L'ERREUR DE SAMPLING # 0,5 %)	- 1 A + 3 %	0,6 x 2,5 %	$\frac{4,5\ \%}{2,5}$ # 2

CONTRADICTION BETWEEN THEORY AND TREND, O_3, 1960-1979

	[a]ERREURS LIMITES DES OBSERVATIONS			[b] DIMINUTION O_3 1960/1979	
	[c] STATISTIQUE	[d] DERIVES & TREND PARASITES POSSIBLES	[e] TOTAL ERREUR POSSIBLE SUR TREND	OBSERVABLE [f] THEORIQUE (RÉDUCTION THÉORIQUE MODÈLE = ERREUR TOTALE)	[g] REEL OBSERVE
OZONE TOTAL	[h] DE L'ORDRE DE ± 1 %	HÉM. NORD [i] + 1,5 % MAX.	[i] HÉM. NORD + 0,5 À 2,5 %	[i] HÉM. NORD - 2,5 À - 0,5 %	[i] HÉMISPHÈRE NORD + 1 À + 6 %
		HÉM.[j] SUD + 1 %	[j] HÉM. SUD 0 À + 2 %	[j] HÉM. SUD - 3 À - 1 %	[j] HÉMISPHÈRE SUD 0 À + 2 %
OZONE UMKEHR 35/45 KM	[h] DE L'ORDRE DE ± 1,5 % À ± 2 %	+ 2 %	0 À + 4 %	- 7,5 À - 3,5 %	+ 5 À + 8 %

Chapter 1: Scientific "evidence"

First of all, it is necessary to request a change in the title and to speak of "summary of scientific data."

Part B should no longer be presented as an affirmation of the validity of the theory, extenuated by some "uncertainties." The title should thus be less oriented [in this direction]. I would propose "Findings including uncertainties and discrepancies."

The details of these "Findings" are open to criticism, and possibly should be completed as a function of the first text project. They should be sent to Messrs. Eggleton, Watson, Ehhalt for the first draft of the survey of the chemistry, modeling and measurments.

On the other hand, it is advisable to go forward with the subject of the sub-chapter treating ozone monitoring, the limits, possibilities and consequences for the validity of Rowland's theory and the limitations in each hypothesis of future risks. I attach two documents of reflections which should at least serve as a basis for a discussion that can be treated by the publication in an appropriate paragraph in the definitive report.

Chapter II: Effect on health and on the environment

It would be advisable to have a detailed criticism of the project that Wiser of the EPA has established, since it has a strong chance of being biased.

The important points to note at present and which might be included formally in the final report are chiefly the following:

1) The correlation between UVB increase and melanoma has not been proven in a significant manner.

2) The correlation between UVB increase and non-melanoma skin cancer /2 (generally not fatal) is based on epidemiological studies whose almost only important variable is latitude. Under these conditions, it is difficult to confirm that this correlation can be linked directly or indirectly to other factors which are themselves correlated to latitudes (temperature, humidity, concentration of carcinogenic traces, light level of UVA and visible light, etc...).

3) There are no other formal tests of appreciable carcinogenic effect on man at the foreseeable rates. The specific tests of UVB on animals are quite small in number in terms of conditions approximating natural conditions (practically, only 1 study on mice published in 1978). The extrapolation to man of such a study would be at least debatable.

4) No demonstration of a serious effect on plants or ecosystems of the increase in UVB within foreseeable limits has been made to this date. A full range of tests has not been carried out; tests have been done only on some species, in conditions which cannot be extrapolated to natural conditions, and they are often contradictory. If the risk were really important, more cohesiveness would have emerged in the conclusions of the studies already published.

5) The possible climatic effects of the CFC are relatively negligible in comparison with other anthropogenic chemicals (CO_2 for example). There is an almost general consensus among the various authors who have done such comparative studies.

6) Finally, and above all, it is advisable to stress the distribution of the possible reduction of O_3 as a function of latitude. All the 2D models agree on this subject. The reduction is negligible in the tropics and maximum in the boreal regions. The result is a very weak increase in UV in the regions which are already receiving most of it, and, on the contrary, a more serious increase in the regions that are weakly irradiated.

Even if we admit that the corresponding positive effect (decrease in

vitamin D deficiency in the Northern regions) is negligible, there results, in any case, a new cause which seriously diminishes the possible risk, cf. fig. 4, recently published by Derwent, who shows that the mean risk of variations in the UVB during 1 year is at worst on the order of 5% of the actual UVB at the equator, although the EPA has announced an increase 10 times greater (44%) to justify the necessity of regulating the CFC. 13

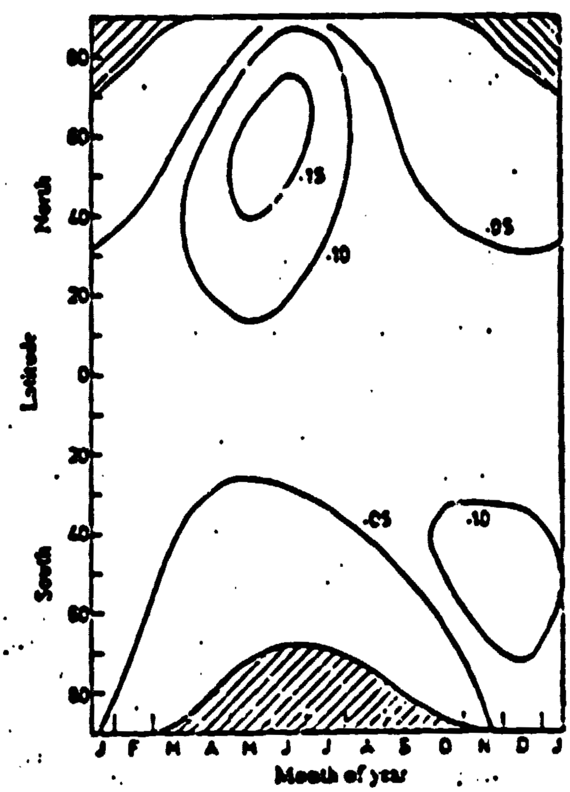


Fig. 4 Ratio of increase in erythemally-weighted UV-B dose from CFC usage to the dose at the Equator.

Chapter 3: CFC Industry

For this subject, it would be advisable to pay attention, independent of the press release accompanying signature to the conventions, the document prepared by M. Parenteau for Munich and to add the following comments:

The French aerosol industry basis its commercial power essentially on some particular characteristics of this product which are developed than in other countries, thanks to the CFC:

a) nonflammable and nonexplosive products with high safety; /4
b) products using very light perfume (which forbids using any component with a slight odor or reacting in the slightest with the perfumes);
c) very finely powdered products which are not wetted (a very small amount of nonvolatile solvent);
d) a high percentage of products for non-water based comestic use (laquers [hair sprays?], perfumes, etc.).

These characteristics allow satisfying a large range of clients, and this industry would be more affected than its counterpart in other countries if it had to lower its "quality" level because of abandoning CFC.

As in most other European countries and Japan, prevention of accidents by fire in France is much more rigorous than in the United States (cf. Table below).

a Nombre de morts par le feu (toutes causes)	
b - Etats-Unis	4 d pour 10.000
- Europe	5 pour 1.000.000
- France	5 pour 1.000.000
c - Japon	1 pour 1.000.000

Key:
a. number of deaths by fire (all causes)
b. United States
c. Japan
d. per

The substitution of inflammable or explosive products for CFC is thus proportionally much more serious in Europe and Japan than in the USA.

Finally, it should be stressed that, in the same context, the regulations concerning industrial installations and sales would cause in France closing many businesses if CFC is replaced by an inflammable product.

Taking these constraints into account limits to 30% the possible reduction without completely disorganizing the aerosol industry in France.